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GHG historical contribution by sectors, sustainable development and equity

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Abstract

Historical contribution to climate change is useful for future commitments to the burden share based on common but differentiated responsibilities as presented by the Brazilian Proposal [UNFCCC. United Nations Framework Convention on Climate Change: Ad Hoc Group on the Berlin Mandate. Implementation of the Berlin Mandate: Additional proposals from Parties, Addendum, Note by the secretariat; 30 May 1997.] according to Equity principle adopted by the United Nations Framework Convention on Climate Change [UNFCCC. United Nations Framework Convention on Climate Change; 1992.]. This paper presents some results of historical greenhouse gases emissions inventories (CO_2 from energy and land use change sectors, CH_4 from enteric fermentation and N_2O from animal waste manure management). It is discussed the differences among historical emissions in terms of development patterns and it is suggested some proposals for climate policy based on the concepts of equity and sustainable development.

Keywords: GHG historical emissions; Sustainable development; Equity

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1. Introduction

The objective of this paper is to present a study on Greenhouse gases historical emissions, Sustainable Development & Equity being carried out at IVIG/COPPE/UFRJ—International Virtual Institute on Global Change of the Coordination of Post Graduation Programs in Engineering of the Federal University of Rio de Janeiro. The study involves an estimate of historical emissions of greenhouse gases from selected human activities. The main objective is to contribute to the debate of shared responsibilities of the countries to the climate change involving the concept of Equity [2,3]. This approach facing the Climate Convention principles has to deal with the "common but differentiated responsibilities and respective capabilities and their social and economic conditions", and needs to offer a solid contribution to the ultimate objective of the UN Framework Convention on Climate Change, as it involves a long-term approach.

The international community is starting to discuss a next commitment period (pos-Kyoto Protocol) and the so-called Brazilian Proposal [1] is one option for the climate change debate on international burden sharing and is already referred to the SBSTA/UNFCCC. The Brazilian Proposal (BP) presents a criterion for the sharing of the burden of mitigation among countries, shifting the focus of the debate: from the emissions to the temperature increase.

The paper presents the results already obtained by our research on historical emissions database at International Virtual Institute on Global Change CO_2 historical emissions (1750–1990) from the energy sector, CO_2 historical emissions (1700–1990) from land-use change [4,5], CH_4 and N_2O historical emissions (1890–1998) due, respectively, to enteric fermentation and animal waste manure management, both from domestic livestock [6]. Some databases were used such as the HYDE [7], CDIAC [8,9].

2. The importance of the gases—CO_2, CH_4 and N_2O and sectors

The contribution to climate change from CO_2 historical emissions due to the energy sector is quite bigger for developed countries in comparison with developing countries [10,4,8].CO_2 historical emission databases from fossil fuel consumption have been focus of analysis with not large differences among different datasets.

It was used the HYDE Database land use change to estimate the land use change historical emissions from 1700 to 1990. It was estimated carbon emissions factors for each

biome [5]. It was inventoried the N_2O and CH_4 historical emissions (1890–1998) due to animal waste manure management and enteric fermentation using the HYDE domestic livestock historical database (cattle, buffalo, pigs, sheep, goats). It was estimated emissions factors for each animal in each country using as basis the IPCC [11] methodologies for inventorying the greenhouse gases emissions factors by animal, by gas and by process (manure and enteric fermentation).

The calculation of CH_4 and N_2O emissions is very important in terms of comparison with the importance of the carbon dioxide emissions. It is well recognizable by expert literature that CO_2 represents the main gas in terms of contribution to climate change, mainly from fossil fuels combustion and also from land use change. Nevertheless, it is quite claimed that other gases need to be inventoried to refine the analysis for the Climate Policy negotiations. Table 1 shows the concentration of CH_4 and N_2O before Industrial Revolution and in 1998 showing a huge increase of both gases in this period.

It can be observed in Table 2 that although the energy sector is the most significant for the period 1750–1990, the cumulative emissions and the concentration of N_2O from Animal Waste Manure Management due to domestic livestock (it is important to emphasize that it is not included the N_2O emissions from animals grazing, what would show a very higher result of the N_2O emissions) and the cumulative emissions and concentration of CH_4 from Enteric Fermentation due to domestic livestock during the period of 1890/1990 are also very important in terms of magnitude.

Table 1
N_2O and CH_4 concentrations before the industrial

	N_2O	CH_4
Concentration before the industrial revolution	About 270 ppb	About 700 ppb
1998 concentration	314 ppb	1745 ppb
Rate of changing the concentration	0.8 ppb/year	7.0 ppb/year
Lifetime in the atmosphere	114 years	12 years

Source: Authors, based on TAR-WGI, 2001 [12].

Table 2
Participation of four sectors of World Cumulative Emissions and world concentrations in Gg Ceq

	CO_2 from energy (fossil fuel) 1750/1990 (Gg C)	CO_2 from land use change 1700/1990 (Gg C)	N_2O from manure management from domestic live stock 1890/1990 (Gg Ceq)	CH_4 enteric fermentation from domestic livestock1890/1990 (Gg Ceq)
Cumulative emissions	212 million	138 million	8 million	45 million
Concentration	123 million	38 million	5.7 million	8 million

Source: Authors, based on IVIGs project results. The three gases were put on GgCeq through the GWP for 100 135 years (TAR, 2001) [12].

3. Historical CH_4 emissions and concentrations due to enteric fermentation

We estimated the CH_4 emissions due to enteric fermentation of domestic livestock (cattle, buffalos, pigs, sheeps, goats, horses, mules and assess) by country since 1890 until 1998. The emission follows a simple rule: the emission factor per animal multiplied for their population. The world populations of these domestic livestock's were obtained from the HYDE domestic livestock population database by country. The emission factors were established using as a basis the IPCC [11].

The atmospheric methane concentration has increased around 1060 ppb (151%) since 1750 and still keeps on increasing nowadays. More than a half of CH_4 current emissions are due anthropogenic sources [12]. The most important atmospheric methane anthropogenic sources are listed in Table 3.

According to Table 3, it is estimated that the most important sources of anthropogenic methane emissions are the rice cultivation, ruminants and the energy sector (mainly fugitive emissions from extraction, production, transportation and processing of fossil fuels).

The world rice cultivation land has increased from 86 Mha in 1935 to 144 Mha in 1985, what means an yearly average of 1.05%. The medium yearly increment was 1.23% between 1959 and 1985 but this tendency is changing in the last decades [11].

Other important methane emission source is the waste. Around 5–20% from CH_4 anthropogenic annual global emission to the atmosphere are due to the anaerobic decomposition and treatment of solid and liquid residues [11]. The production of methane from liquid residues treatment in anaerobic conditions is estimated between 30 and 40 Tg per year, what represents around 8–11% of global anthropogenic emissions of CH_4 [11]. From this total, it is estimated that the industrial sector is responsible for 26–40 Tg per year, while the residential and commercial sectors are responsible for around 2 Tg per year.

Another very important source of methane emissions are the ruminants, and the methane is produced naturally in their digestive system, the called enteric fermentation process. In the 1990s, the ruminants were responsible for about 28% of all CH_4 anthropogenic emissions [12].

Table 3
CH_4 global emissions according to different authors in selected years due to anthropogenic sources

Reference	Fung et al. (1991)	Hein et al. (1997)	Levieveld et al. (1998)	Houweling et al. (1999)
Base year	Decade of 80 (Tg CH_4/year)	(Tg CH_4/year)	1992 (Tg CH_4/ year)	(Tg CH_4/year)
Energy (fugitive emissions from fossil fuels)	75 (21%)	97 (28%)	110 (33%)	89 (28%)
Land fill	40 (11%)	35 (10%)	40 (12%)	73 (23%)
Ruminants	80 (23%)	90 (26%)	115 (35%)	93 (30%)
Waste treatment			25 (8%)	
Rice cultivation	100 (29%)	88 (25%)		40 (13%)
Biomass burning	55 (16%)	40 (11%)	40 (12%)	20 (6%)
Others				
Total (anthropogenic)	350 (100%)	350 (100%)	330 (100%)	315 (100%)

Source: Authors, based on TAR-WGI (2001) [12].

The quantity of methane produced depends on the animal and region of the world. The most important ruminants in terms of CH_4 emissions are the cattle, buffalo and sheep. We calculated the concentrations (using the decay time as 12 years) of CH_4 in the year of 1990 due to emissions from 1890 to 1990 (Table 2). CH_4 concentration in 1990 (due to emissions from 1890 to 1990) is 8 million GgCeq, not negligible, around 7% in comparison with the CO_2 concentration due to fossil fuels in 1990 (from 1750 to 1990) equal to 123 million GgC (Table 2).

4. Historical N_2O emissions and concentrations due to manure management

According to Table 4, the N_2O emissions due to agricultural land is the most important source of emission, around 52%, followed by the cattle, responsible for around 26% of the total anthropogenic emissions of N_2O.

We calculated the N_2O emissions due to Animal Waste Manure Management of domestic livestock using the HYDE domestic livestock population, and the inventory methodologies of the IPCC. (It is important to emphasize that it is not included the N_2O emissions from animals grazing, what would show a very higher result of the N_2O emissions). We also calculated the atmospheric concentration of N_2O in the year of 1990 considering an exponential decay time of 114 years according to TAR-WG1 [12]. N_2O concentration in 1990 (due to emissions from 1890 to 1990) is 5.7 million GgCeq, not negligible, around 5%, in comparison with the CO_2 concentration due to fossil fuels in 1990 (from 1750 to 1990) equal to 123 million GgC (Table 2).

5. Historical CO_2 emissions and concentrations due to land use change by country

It is well recognized that the most important source of historic CO_2 emission is the energy sector and the historic CO_2 emission due to fossil fuel by country is already established using consolidated energy statistics [8]. The second greatest anthropogenic source of CO_2 is the land use change. There are some estimates of historic CO_2 emissions due to land use, land use change and forestry presenting large differences. A historical CO_2 land use change emissions database is quite useful for academic and scientific purposes to understand the development patterns at national and regional levels. The patterns of land use change are being studied for several international programs (Land-Use and Land-Cover Change—LUCC, Human Interaction in Past Environmental Changes—PAGES, Human Impacts on Terrestrial Ecosystems—HITE). There are several uncertainties

Table 4
N_2O global emissions according to different authors in selected years due to anthropogenic sources

Reference	Mosier et al. (1998) and Kroeze et al. (1999)	Olivier et al. (1998)
Year base	1994 (Tg N/ano)	1990 (Tg N/ano)
Agricultural land	4.2 (52%)	1.9 (46%)
Burning biomass	0.5 (6%)	0.5 (12%)
Industrial sources	1.3 (16%)	0.7 (17%)
Cattle	2.1 (26%)	1.0 (25%)
Total (anthropogenic)	8.1 (100%)	4.1 (100%)

Source: Authors, based on TAR-WGI (2001) [12].

involved in this issue and different methodologies, and concepts show different patterns of land use change. The historic CO_2 emission from land use change involves uncertainties greater than fossil fuels.

The CO_2 emissions patterns from land use change among the developed and developing countries differ in terms of time. As commented by Goldewijk [13], the land conversions (above ground) of the developed and temperate regions has occurred in the second half of the 19th century, while the tropical and developing countries has converted their lands to pasture and cropland in the second half of the 20th century. The inclusion of emissions from the soil (below ground) should increase the emissions from the temperate countries, once the organic carbon in cold soils is much higher than hot soils.

6. Importance of historical emissions, sustainable development and equity principle

The discussion about historical emissions is deeply linked to the Sustainable Development and Equity. According to Newmayer [14], historical emissions accountability is important at three aspects: to not ignore the physical laws that give rise to the environmental problem of global warming, to not give a retrospective licence to past emitters and, to not privilege those who lived in the past with the opportunity to benefit from emissions. Some objections against historical accountability will be commented. One argument against the historical analysis of the emissions for the attribution of responsibilities is that it was not known the greenhouse effect in the past. Nevertheless, it is important to observe this question in a deeper way. "Two recurring questions are whether 'responsibility' presumes intent or at least knowledge about the harmful consequences of one's behaviour. In the context of international diplomacy, the consensual answers seem to be that an actor may be considered 'responsible' without (proof of) malicious intent, but not if he/she could not have known—on the basis of the state of (scientific) knowledge at the time—that his/her behaviour was causing (substantial) damage" [15].

The choice for a kind of development based on fossil fuel use as energy source since the Industrial Revolution resulted in a tremendous greenhouse gases emissions and climate change. The question here discussed is whether the issue of Responsibility is a consequence of that and in which level, even without the knowledge of the phenomena of greenhouse effect in the past. Besides, the issue of the amplitude of knowledge emerges here. How far is considered the knowledge in terms of responsibility? Science has already pointed out GHG effect phenomena since the century XVIII. The greenhouse effect was first observed, by Fourier during the French Revolution and in 1896, and Svante Arrenius created a model to study the influence of CO_2 accumulated in the atmosphere in the Earth surface temperature [16].

Even considering that in the past before 1900, the greenhouse gases (GHG) emissions were less important in magnitude, they can represent a great impact on climate system [17]. It is important to account historical emissions to understand the evolution of development for different regions and countries, which present very large differences of responsibilities.

Besides, several uncertainties involve the climate system science and it is necessary to acquire more confidence in the data and to go further in the researches to adopt a database and to discard others. An interesting example of how one uncertainty can affect the results about responsibilities is the non-linearity's involving the climate modelling such as the additional radiative forcing due to additional concentrations of CO_2 [12]. At 300 ppmv

CO_2 concentration, an additional ppmv causes 0.018 W/m^2 radiative forcing, while at twice the concentration, at 600 ppmv, the effect of an additional ppmv is only 0.009 W/m^2, which is half of the effect. It means that 'early emissions' result in a bigger effect than 'late emissions' [17]. Therefore, it seems that the historical emissions are important to be taken into account for a sustainability analysis.

7. Equity, sustainable development, and climate policy proposals

"It is often said that equity is the key to acceptability. This is probably true in general terms, but it may be useful to distinguish between distributive justice and procedural equity" [18].

Several proposals are being discussed to burden-sharing on climate policy. One interesting analysis that compares all of them involves criteria for some Equity Principles [15] and Operational Requirements [19]. As equity principles, it was recognized that a proposal has to be comprehensive in terms of 'responsibility', 'need', and 'capacity'. As operational requirements it was taken into account that a proposal has to have 'universal applicability', 'easy to make operational', 'simplicity', 'allows to future refinements', 'allows for flexibility' and 'allows for country-specific circumstances'. Equity is commonly used as synonymous of 'justice' and 'fairness' although these concepts can achieve different meanings. "The principles of justice exist prior to and independently of any phenomenon to be judged. Fairness consists of individual perceptions of what is reasonable under the circumstances, often in reference to how a principle of justice regarded as pertinent should be applied. Therefore, justice can take priority over fairness in decision-making with respect to equity concerns. Such a difference appears to correspond with the UNFCCC article 3 notion of 'common but differentiated responsibilities'" [20].

The Brazilian Proposal had a relatively striking impact in two specific aspects: it included accounting for past emissions of several countries, including a historical component in their growth models, while also introducing a penalty system through a Financial Fund for countries failing to meet their greenhouse gases emissions reduction targets, issue not discussed here. All the signatories to the Convention on Climate Change rated the Brazilian Proposal as innovative. According to the comparative study of Torvanger and Ringius [20], the Brazilian Proposal is the best in terms of Fairness but is the worst in terms of operational requirements. It is important to note that the Brazilian Proposal does not necessarily deal with a specific initial date in the past. It can be applied to a certain period of time by choice. The choice of the starting date implies in different share of responsibilities among regions or groups of countries. It is important to evaluate whether the approach of the Brazilian Proposal is compatible with the Kyoto Protocol, what shifts would be required compared to the current Protocol rules and the international negotiation process. On other hand the proposal by Brazil could be shifted to incorporate the efforts done in the Kyoto Protocol.

It is important to observe that point for validating the models against observed climate, the analysis should also include factors influencing global climate other than the greenhouse gases covered by the Convention and the Kyoto Protocol. The inclusion of other gases not controlled by the UNFCCC involves more complex climate models. It is necessary to show which gases are really important not only in terms of the climate system but also in terms of development patterns. We propose to differentiate the meaning of the different gases along the historical emissions such as earlier discussed by other authors

[21,22]. For that, it can be given different weights of importance to the GHG depending on their sources. That is because, although a tCeq is not different for the global warming, it can be associated to different consumptions patterns. Table 2 shows concentrations from historical GHG emissions due to four sectors—fossil fuel, land use change, manure management and enteric fermentation. To illustrate our proposal for future commitments taking into account a more sustainable development, CH_4 emissions from domestic livestock (manure management and enteric fermentation) should be less weighted than N_2O emissions from industrial processes, and also less weighted than CO_2 emissions from fossil fuels [3], for example. In that hypothesis the N_2O and CH_4 concentration increases from pre-Industrial Revolution until 1998 presented in Table 1 would represent a different meaning depending on the activity source.

Another issue is related to the land use change emissions: they should be expressed by the areas of the countries taking into account the emissions per hectare or per square kilometer. This would prevent the analysis that compare emissions from land use changes of small countries like Portugal and Belgium to emissions of big countries like Canada and Brazil. We believe that it conceives almost all the principles and requirements proposed by UNFCCC.

The issue of Climate Change is based on several types of uncertainties. The dominant view among the climate specialists is that the pace of global warming stepped up during the XIX and XX centuries, caused by anthropogenic emissions of gases such as carbon dioxide, bouncing back part of the heat emitted by the earth and resulting in the greenhouse effect. Although this topic is still wrapped in some scientific doubts, they are a minority: among other matters there are disagreements on the importance of the increase in global temperatures. There are even more differences with regard to their real consequences on future generations and even their causes.

8. Conclusions and recommendations

Since the parties are presumed to have control over their annual emissions and one of the Convention requirement is that Parties report their annual emissions, given to a natural tendency to compare the annual emissions of Parties and thus implicitly to associate the emissions to the relative responsibilities in inducing the climate change [1], we suggest that the Convention induces the Parties to report their historical emissions and the IPCC develops methodologies to guide it. It will be necessary to evaluate the capacity of the countries to inventory their emissions related to the past as much as to foresee future emissions. Although such a proposition involves targets not easily achieved, mainly for the developing countries, the historical inventories of RIVM, WRI, CDIAC-ORNL, IIASA, Woodshole Research Center and AFEAS are good example of the possibility of it. The IPCC Guidelines for National Greenhouse Gas Inventories is also the first step in this way.

The developed countries and the countries with big population are the larger emitters. Depending on the sector, some developing countries with smaller populations can present huge emissions. Brazil, for example, is the second in the ranking of iron production in the world, being responsible for around 20% of the global iron production [23]. Nevertheless, aiming to attend to the sustainable development and equity principles of ‘need’ and ‘responsibility’, we can consider different weights for the sectors. If we establish less weight for the activities of the sectors that are directly linked to ‘basic needs’ for the human survival, such as the enteric fermentation from domestic livestock, and also basic needs due

to the land use change sector, the results in terms of different responsibilities among the countries will substantially change.

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